FELDSPAR UPGRADING FOR MAGDALEN SILICA INC.

PROGRESS REPORT NO. 1

G.I. MATHIEU

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FELDSPAR UPGRADING PROJECT

FOR MAGDALEN SILICA INC.

Progress Report No. 1

by

G.I. Mathieu

PURPOSE OF INVESTIGATION

To upgrade, at minimum cost, a primary feldspar concentrate (produced previously by treating the Magdalen silica sand in CANMET pilot plant) from 14.3% Al_2O_3, 8.4% K_2O, 1.9% Na_2O and 0.61% Fe_2O_3 to finished feldspar products of both "glass" and "ceramic" grade, with the following chemical and size specifications:

Table 1 - Requirements of commercial feldspars

Specifications	Category of Feldspar	
	Glass	Ceramic (Porcelain)
Chemical: Alumina (Al_2O_3) Alkalis (K_2O + Na_2O) Iron oxide (Fe_2O_3)	 18.5 ∓ 0.6% 11.5 ∓ 1% 0.1%	 18.0% (minimum) 13.0% (minimum) 0.08% (maximum)
Size:	98% within 600 and 150 µm	100% minus 74 µm (minus 45 µm preferred)

CHEMICAL ANALYSIS, SIZE DISTRIBUTION AND MINERALOGICAL COMPOSITION OF HEAD SAMPLE

CHEMICAL ANALYSIS

A representative sample was riffled out from a 40 kg lot of primary feldspar and analysed with the results shown in Table 2.

Table 2 - Chemical analysis of head sample

Feldspar constituents, %				Silica %		Metal Oxides %			Lost on Ignition %
Al_2O_3	K_2O	Na_2O	CaO	Total	Quartz	Fe_2O_3	MgO	TiO_2	LOI
14.3	8.4	1.90	0.46	72.9	33.4	0.61	0.26	0.11	0.9

SIZE ANALYSIS

A 300-g cut from the head sample was screened on a U.S. Series of sieves. The sized fractions were weighed and assayed for the feldspar components, total silica and major metal oxides. These results are reported in Table 3.

Table 3 - Size analysis of head sample

Part I - Weight and Analysis

Size		Weight	Analysis, %							
µm	U.S. No.	%	Al_2O_3	K_2O	Na_2O	CaO	SiO_2	Fe_2O_3	MgO	TiO_2
-600+300	30 x 50	20.1	17.6	10.1	2.29	0.80	67.2	0.60	0.24	0.07
-300+212	50 x 70	50.2	16.0	9.7	1.98	0.43	70.9	0.52	0.23	0.06
-212+180	70 x 80	16.3	12.8	7.1	1.67	0.34	76.0	0.60	0.29	0.09
-180	minus 80	13.4	8.4	4.2	1.17	0.35	83.2	0.93	0.40	0.23
Feed (calcd)		100.0	14.8	8.6	1.88	0.48	72.6	0.66	0.26	0.09

Part II - Material Balances

Size		Distribution, %							
µm	U.S. No.	Al_2O_3	K_2O	Na_2O	CaO	SiO_2	Fe_2O_3	MgO	TiO_2
-600+300	30 x 50	23.9	23.6	24.4	33.6	18.5	19.6	18.2	15.7
-300+210	50 x 70	54.3	56.5	52.8	45.1	49.0	43.5	43.6	33.6
-210+180	70 x 80	14.1	13.4	14.5	11.5	17.1	15.9	17.9	16.4
-180	minus 80	7.6	6.5	8.3	9.8	15.4	21.0	20.3	34.3
Total (calcd)		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Examination of the above results suggests a separate treatment of the coarser material (e.g., the fractions larger than 210 μm) since it already contains 16.4% Al_2O_3, 9.8% K_2O and 2.1% Na_2O and would thus need very little beneficiation to satisfy the alumina and alkali requirements of the glass and ceramic feldspars. On the other hand, the finer fractions at 10.8% Al_2O_3, 5.8% K_2O and 1.4% Na_2O would require more extensive processing to obtain the desired grade.

MINERALOGICAL EXAMINATION

The mineralogy of the head sample was studied in detail. It is summarized below.

Table 4 - Mineralogical composition of head sample

CATEGORY	NAME	FORMULA	APPROXIMATE %
Silica	Quartz	SiO_2	25-30
Feldspars	Orthoclase	$KAlSi_3O_8$	50-55
	Albite*	$NaAlSi_3O_8$	14-16
	Anorthite* (lime feldspar)	$CaAl_2Si_2O_8$	1- 2
Metal oxides	Ilmenite	$FeTiO_2$	0.2-0.3
	Hematite	Fe_2O_3	0.1-0.2
	Limonite	$HFeO_2nH_2O$	0.1-0.2
	Rutile	TiO_2	0.05-0.1
Ferro-magnesians**	Chlorite	$A_6(AlSi_3O_{10})(OH)_8$	0.1-0.3
	Biotite	$AB_3(Al,Si)_4O_{10}(OH,F)_2$	0.05-0.1
	Pyroxene	$AB(Si_2O_6)$	0.01-0.05
	Amphibole	$A_2B_5(Si,Al)_8O_{22}(OH)_2$	Trace
Clay (Fe-rich type)		Fe, Al, Si...	0.1-0.2
Spinel (Cr-Fe-Al type)		$(Mg, Fe, Cr)Al_2O_4$	Trace
Zircon		$ZrSiO_4$	Trace
Apatite		$A_5(RO_4)_3(F,OH,Cl)_3$	Trace

* Often occurring in solid solution termed plagioclase.
**In the formulas of ferromagnesians; A = K for biotite, Na, Ca for amphibole, Na, Ca, Mg, Fe for pyroxene and Mg, Fe, Al, Mn for chlorite, and B = Mg, Fe and Al.

The important mineralogical observations were as follows:

1) The potassium (K) and plagioclase (Na, Ca) feldspars are largely free from quartz, but highly contaminated by rutile and iron-bearing mineral intergrowths and inclusions. The latter are extremely fine and consist essentially of ilmenite (or titano-hematite).
2) Ilmenite, hematite, rutile, chlorite and biotite also occur as discrete particles (up to about 50%).
3) Limonite and the iron-rich clay mineral are present as thin coating on the quartz and, particularly, on the feldspar grains.
4) Pyroxene, amphibole and zircon are extremely rare; only one grain of apatite and spinel were observed in the many fields examined.
5) It is noticeable that all the iron-bearing species identified are paramagnetic and should thus be easily separable by high-intensity magnetic separation, provided sufficiently liberated.

This mineralogy indicates the necessity of, at least, three main unit operations for upgrading the primary feldspar to either glass or ceramic specifications, namely:

1) flotation or magnetic separation for removing the liberated (acid insoluble) iron minerals;
2) selective flotation for separating the feldspars from the quartz;
3) acid leach to dissolve the iron oxide coating on the grains of feldspar minerals.

In addition to these, fine grinding to minus 74 (or minus 45) µm will be necessary to satisfy the size requirements of the ceramic grade. Because of the extremely low iron specification for some ceramic feldspar (0.08% Fe_2O_3) and of the fineness of the ilmenite inclusions, a high gradient magnetic separation stage would likely be required after the fine grind.

INITIAL TESTWORK

Prior to investigate integrating flowsheets for upgrading the feldspars, it was thought advisable (1) to study under various conditions each main unit operation, and (2) to assess the interaction of some of these, e.g., magnetic removal of iron on subsequent acid leach, grinding prior to flotation, etc.

REMOVAL OF LIBERATED IRON MINERALS

Flotation

Because a flotation step (i.e., the feldspar-quartz separation) is necessary in the upgrading circuit, differential flotation of the ferrous minerals appeared at first as an attractive method for eliminating the iron-bearing minerals. However, up to now the efficiency and the selectivity of any iron flotation, even after a 15 minute scrubbing at high alkalinity, were not satisfactory most likely because of the residual reagents from previous location on the surface of the raw feldspar product.

Two iron flotation systems were investigated. In a first series of tests, a new collector identified as Reagent XC-62 and working at neutral pH was experimented with, while the second approach used the conventional petroleum sulphonate-sulphuric acid combination (pH = 2.0-2.5). In both cases, the iron recoveries using small amounts of collector were insufficient. On the other hand, relatively large dosage of collectors improved the iron extraction but entrained severe losses of feldspar (i.e., about 10%). Under the best conditions, the iron oxide level was reduced from 0.6% to merely 0.4% Fe_2O_3. Further testwork on iron flotation was delayed after the leaching or the grinding stages, if deemed useful.

Magnetic Separation

Both wet (Sala) and dry (Stearns) high-intensity magnetic separations were also tested under various conditions for iron removal. Since the primary feldspar would be a wet product in a plant circuit, the Sala HGMS wet separator was investigated first. With this unit high magnetic fields and low flowrates were required to allow for the collection of the least magnetic grains, e.g., the ferromagnesian minerals and the middlings low in iron oxides, as examplified by the results reported in Table 5. On the other hand, the dry separation proved to be more selective, while nearly as effective, with much less feldspar lost for similar iron rejections (see Tests MS-2, MS-4 and MS-5, in particular).

Difficulties in the wet separation and, to a lesser extent, in the dry one were attributed to residual flotation reagents on the surface of the minerals, which caused unselective agglomeration of the grains. With the Sala separation, another problem was identified, particularly at higher flow rate, i.e. the drag force of the liquid detached the less magnetic particles from the collecting matrix. These then contaminated the non-magnetic feldspar product.

Table 5 - Results of Magnetic Separation

Test	Separator (Conditions)	Products	Wt %	Analysis* %				Distribution %			
				Fe_2O_3	MgO	TiO_2	Feld-spar*	Fe_2O_3	MgO	TiO_2	Feld-spar
MS-1	Sala (0.7 Tesla, 20 mm/s)	Fe conc (mags)	8.7	3.56	1.70	0.51	65.4	49.3	40.9	48.0	8.1
		Feldspar conc (non-magnetic)	91.3	0.33	0.11	0.06	70.2	50.7	59.1	52.0	91.9
		Feed (calcd)	100.0	0.61	0.25	0.10	68.9	100.0	100.0	100.0	100.0
MS-2	Sala (0.9 Tesla, 20 mm/s)	Fe conc (mags)	11.0	3.29	1.32	0.46	57.3	58.4	62.3	58.7	9.1
		Feldspar conc (non-magnetic)	89.0	0.28	0.10	0.04	70.4	41.6	37.7	41.3	90.9
		Feed (calcd)	100.0	0.62	0.24	0.09	69.0	100.0	100.0	100.0	100.0
MS-3	Sala (0.9 Tesla, 7.5 mm/s)	Fe conc (mags)	15.5	2.28	1.13	0.42	63.4	61.7	67.5	65.8	14.3
		Feldspar conc (non-magnetic)	84.5	0.26	0.10	0.04	69.9	38.3	32.5	34.2	85.7
		Feed (calcd)	100.0	0.57	0.26	0.10	68.9	100.0	100.0	100.0	100.0
MS-4	Sala (0.9 Tesla, 8.3 mm/s) & Stearns (0.5 Tesla, minimum gap)	Fe conc (Sala)	12.7	2.79	0.88	0.44	65.1	59.3	59.3	62.9	12.0
		Fe conc(Stearns)	1.3	2.84	2.23	0.55	60.1	6.2	12.1	8.1	1.1
		Total Fe conc	14.0	2.80	1.00	0.45	64.8	65.5	71.3	71.0	13.1
		Feldspar conc	86.0	0.24	0.08	0.03	60.1	34.5	28.7	29.0	86.9
		Feed (calcd)	100.0	0.60	0.24	0.09	69.1	100.0	100.0	100.0	100.0
MS-5	Stearns (0.5 Tesla, minimum gap)	Fe conc (mags)	5.0	7.00	2.80	1.16	63.1	57.4	56.2	55.0	4.7
		Feldspar conc (non-magnetic)	95.0	0.28	0.12	0.05	67.4	42.6	45.8	45.0	95.3
		Feed (calcd)	100.0	0.61	0.26	0.11	100.0	100.0	100.0	100.0	100.0

*Calculated using the following formula:

$$\text{Feldspar (\%)} = \left(\frac{K_2O}{16.92} + \frac{Na_2O}{11.82} + \frac{CaO}{20.16}\right) 100$$

Further analyses of the main products gave the following results:

Test No. (Separator)	Iron Concentrate					Feldspar Concentrate					
	Al_2O_3	K_2O	Na_2O	CaO	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	SiO_2	Quartz
MS-2 (Sala)	14.5	7.0	1.9	1.22	69.7	13.7	8.4	2.2	0.43	74.2	26.7
MS-4 (Sala)	13.6	7.3	1.9	1.02	69.4	-	-	-	-	-	-
(Stearns)	15.4	6.3	2.1	1.21	70.1	13.9	8.6	2.0	0.43	73.1	27.7
MS-5 (Stearns)	14.8	6.0	2.0	2.15	61.7	14.3	7.9	2.1	0.43	74.2	27.9

In conclusion, it would be advisable to set the magnetic separation stages towards the end of the treatment, i.e., after flotation and leaching for the glass feldspar and after the grinding stage for the ceramic grade, in order to avoid the agglomeration problem.

FELDSPAR-QUARTZ SEPARATION

To accomplish the feldspar-quartz separation, the non-HF selective flotation method, developed previously, was first selected for economy and safety. Because of the residual chemicals on the feed material, a pre-treatment was indicated to clean or refresh the surfaces of the grains. With this aim, fine grinding, scrubbing and acid leaching were investigated with success. In each case, the differential flotation was tested at three levels of collectors, i.e., at a low concentration to obtain the best possible grade, at high dosage to maximize the feldspar recovery and finally, at an intermediate level in attempt to optimize both grade and recovery. Results up to now have shown that good results could be obtained with and without grinding (see Table 6), albeit the former required much more reagent. The flotation after acid leach is now underway and will be reported later.

Table 6 - Conditions and results of feldspar separation flotation

Procedure (Test)	Reagents Consumed Kg/t			Analysis of Feldspar Concentrates, %			Feldspar Recovered in Process %
	NaOH	H_2SO_4	PDD	Al_2O_3	K_2O	Na_2O	
Grind and float (GF-1,2,3)	-	5.0	3.7	18.1	10.7	2.5	87.3
		5.0	4.5	17.6	10.5	2.5	93.7
		5.2	4.0	17.9	10.6	2.5	91.2
Scrub, deslime and float (SF-1,2,3)	5.0	3.6	1.1	18.1	10.8	2.6	90.3
	5.0	3.8	1.3	17.3	10.5	2.5	94.0
	5.0	3.8	1.2	18.0	10.8	2.5	92.4
Acid leach, alkali scrub, deslime and float (AAF-1,2,3)	5.0	100*+2.8	0.55	18.4	11.2	2.6	90.6
	5.0	100*+3.0	0.65	17.8	10.9	2.5	95.8
	5.0	100*+2.9	0.60	18.2	11.0	2.6	94.1

*Estimated H_2SO_4 consumed in leaching for 6% moisture lost in the cakes and ten reuses of acid.

A combined representative sample of the feldspar concentrates produced in the SF series of tests was screened on a 250 µm metric sieve (i.e., U.S. No 60 equivalent) and the fractions analysed for the main components with the following results.

Table 7 - Size Analysis of Flotation Products

Products	Al_2O_3	K_2O	N_2O_3	CaO	SiO_2	Fe_2O_3	MgO	TiO_2
Silica flot tail (+250 µm)	8.6	3.8	1.2	0.25	-	0.63	0.32	0.11
Feldspar concentrate (+250 µm)	18.4	11.2	2.3	0.72	66.0	0.50	0.26	0.07
Feldspar concentrate (-250 µm)	16.5	10.1	2.4	0.52	68.5	0.75	0.45	0.18
Silica flot tail (-250 µm)	2.7	1.0	0.3	0.09	-	0.23	0.15	0.07

These results suggest the adoption of a sized split-flotation technique with additional cleaning of the feldspar concentrate from the fine fraction for possible improvement of the results. Testing of this approach is now underway and results will be reported in the near future.

APPENDIX I - FELDSPAR-QUARTZ SEPARATION FLOTATION

Table A - Effects of Grinding to Minus 74 µm

Part 1 - Reagents and Conditions

Operation	Time min	Density % solid	Reagents Kg/t		pH
			H_2SO_4	PDD*	
Grinding	4 x 40	60	-	-	-
Conditioning					
Test GF-1	5	60	4.0	3.7	2.1-2.2
Test GF-2	5	60	4.0	4.5	2.1-2.3
Test GF-3	5	60	4.2	4.0	2.0-2.1
Flotation	4	25	1.0	-	2.3-2.6

Part 2 - Weight and Analysis of Products

Test	Products	Wt %	Analysis, %									
			Feldspar components				Total Feldspar	Silica		Oxide		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
GF-1	Feldspar conc	73.4	18.1	10.7	2.5	0.55	87.1	66.0	9.4	0.68	0.25	0.10
	Flot tail	26.6	7.5	3.6	1.4	0.36	44.9	85.8	63.1	0.55	0.22	0.11
GF-2	Feldspar conc	76.9	17.6	10.5	2.5	0.56	85.9	66.8	10.9	0.67	0.21	0.09
	Flot tail	23.1	3.7	1.7	0.9	0.21	19.3	92.2	80.0	0.47	0.18	0.12
GF-3	Feldspar conc	75.0	17.9	10.6	2.5	0.47	86.1	66.5	10.8	0.71	0.24	0.09
	Flot tail	25.0	4.4	2.4	1.1	0.28	24.9	90.7	74.5	0.35	0.13	0.10

Part 3 - Distribution %

Test	Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
GF-1	Feldspar conc	87.0	89.1	83.1	80.8	87.3	68.0	29.2	77.4	75.7	71.6
	Flot tail	13.0	10.9	16.9	19.2	12.7	32.0	70.8	22.6	24.3	28.4
GF-2	Feldspar conc	94.0	95.4	90.2	89.9	93.7	70.7	31.2	82.6	79.5	71.4
	Flot tail	6.0	4.6	9.8	10.1	6.3	29.3	68.8	17.4	20.5	28.6
GF-3	Feldspar conc	92.4	92.9	87.2	83.4	91.2	68.7	30.3	85.9	84.7	69.2
	Flot tail	7.6	7.1	12.8	16.6	8.8	31.3	69.7	14.1	15.3	30.8

APPENDIX I (continued)

Table B - Effects of Alkali Scrubbing

Part 1 - Reagents and Conditions

Operation	Time min	Density % solid	Reagents Kg/t			pH
			NaOH	H_2SO_4	PDD	
Scrubbing (Desliming 2X)	15	75	5	-	-	13.6
Conditioning:						
Test SF-1	5	60	-	2.6	1.1	2.1-2.2
Test SF-2	5	60	-	2.8	1.3	2.0-2.1
Test SF-3	5	60	-	2.8	1.2	1.8-1.9
Flotation	4	25	-	1.0	-	2.3-2.5

Part 2 - Weight and Analysis of Products

Test	Products	Wt %	Analysis, %									
			Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
SF 1,2,3	Feed	100.0	14.2	8.3	2.1	0.50	69.2	73.2	28.6	0.62	0.23	0.10
	Slimes	1.0	12.3	3.8	1.8	2.40	47.6	61.5	31.3	6.90	4.29	0.59
	Deslimed feed	99.0	14.3	8.4	2.1	0.48	69.7	73.4	28.6	0.56	0.19	0.09
SF-1	Feldspar conc	71.4	18.1	10.8	2.6	0.53	88.4	66.3	9.9	0.59	0.20	0.09
	Flot tailing	27.6	4.9	2.1	1.1	0.24	22.9	90.3	75.7	0.44	0.17	0.08
SF-2	Feldspar conc	75.5	17.3	10.5	2.5	0.61	86.3	67.5	12.1	0.58	0.16	0.08
	Flot tailing*	24.5	3.5	1.4	0.7	0.16	15.0	92.5	82.1	0.60	0.28	0.11
SF-3	Feldspar conc	73.4	18.0	10.8	2.5	0.59	87.9	66.3	9.8	0.55	0.19	0.11
	Flot tailing*	25.6	4.5	1.5	1.0	0.27	18.7	91.2	79.7	0.50	0.22	0.10

*Averaged from two tests

Part 3 - Distribution

Test	Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
SF-1,2,3	Slimes	0.9	0.5	0.9	4.8	0.7	0.8	1.1	11.2	18.5	6.0
SF-1	Feldspar conc	89.7	92.5	85.2	81.0	90.3	65.0	25.0	68.9	61.4	70.0
	Flot tailing	9.4	7.0	13.9	14.2	9.0	34.2	73.9	19.9	20.1	24.0
SF-2	Feldspar conc	93.0	95.4	90.8	87.7	94.0	68.7	30.9	66.5	51.9	65.0
	Flot tailing	6.1	4.1	8.3	7.5	5.3	30.5	68.0	22.3	29.6	29.0
SF-3	Feldspar conc	91.2	94.9	87.0	82.1	92.4	67.0	25.8	67.4	58.4	71.4
	Flot tailing	7.9	4.6	12.1	13.1	6.9	32.2	73.1	21.4	23.1	22.6

APPENDIX I (continued)

Table C - Acid - Alkali Treatment prior to Flotation

Part 1 - Reagents and Conditions

Operation	Time min	Density % solid	Reagents Kg/t			pH
			H_2SO_4	NaOH	PDD	
Acid-leach*	360	50	40e	-	-	0.1
Alkali scrubbing & Desliming(2X)	10	75	-	5.0	-	13.1
Conditioning:						
Test AAF-1	5	60	1.9	-	0.60	2.1-2.3
Test AAF-2	5	60	2.1	-	0.70	2.0-2.2
Test AAF-3	5	60	2.0	-	0.65	2.2-2.3
Flotation	4	24	0.9	-	-	2.3-2.6

Part 2 - Weight and Analysis of Products

Test	Products	Wt %	Analysis, %									
			Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
AAF 1,2,3	Feed	100.0	14.8	8.8	2.1	0.35	71.7	72.6	27.4	0.20	0.07	0.08
	Slimes	0.4	11.5	4.5	2.1	2.09	54.8	68.0	35.0	2.27	1.58	1.43
Feed	(Leached & Deslimed)	99.6	14.8	8.8	2.1	0.34	72.3	72.9	27.8	0.19	0.06	0.07
AAF-1	Feldspar conc	73.7	18.4	11.2	2.6	0.34	89.9	66.3	9.4	0.21	0.05	0.06
	Flot tail	25.9	5.1	2.3	0.9	0.29	22.6	90.6	76.7	0.13	0.08	0.09
AAF-2	Feldspar conc	77.7	17.8	10.9	2.5	0.33	87.2	67.6	12.2	0.20	0.05	0.07
	Flot tail	21.9	3.1	1.2	0.5	0.20	12.3	94.2	87.0	0.14	0.09	0.09
AAF-3	Feldspar conc	76.3	18.2	11.0	2.6	0.40	89.0	66.6	10.3	0.20	0.05	0.06
	Flot tail	23.3	4.2	1.7	0.7	0.31	17.5	92.3	81.8	0.16	0.10	0.09

Part 3 - Distribution %

Test	Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O	MgO	TiO_2
AAF-1,2,3	Slimes	0.3	0.2	0.4	2.4	0.3	0.4	0.5	4.6	9.0	7.4
AAF-1	Feldspar conc	90.9	93.1	88.8	75.1	96.1	67.0	25.7	77.0	58.3	60.5
AAF-2		95.0	96.8	94.3	83.4	95.9	71.5	33.1	79.7	60.3	70.0
AAF-3		93.1	95.3	92.0	78.9	94.1	70.0	70.4	76.7	56.5	63.6

APPENDIX II - SIZED SPLIT FLOTATION

Part 1 - Reagents and Conditions

Operation		Time min	Density % solid	Reagents			pH
				NaOH	H_2SO_4	PDD*	
Scrubbing (Desliming 2X) Screening (±250 µm)		15	75	5	-	-	13.5
Conditioning	Test C + F-1	5	57	-	0.85+1.05	0.45+0.70	2.0-2.3
	Test C + F-2	5	57	-	0.95+1.15	0.55+0.80	2.0-2.2
(+250 µm)	Test C + F-3	5	57	-	0.90+1.10	0.50+0.75	2.1-2.2
Flotation:	Tests C-1,2,3	4	25	-	0.5	-	2.4-2.7
1st flotation	Tests F-1,2,3	4	23	-	0.5	-	2.3-2.6
2nd flotation		4	17	-	0.3	0.25	2.2-2.5

Part 2 - Results (Overall Basis)

Test	Products	Wt %	Analysis, %									
			Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
C+F 1,2,3	Feed	100.0	14.2	8.4	2.0	0.46	68.9	72.6	29.3	0.60	0.31	0.12
	Slimes	0.9	12.5	3.6	2.2	1.71	48.4	59.6	31.6	6.30	5.23	0.80
	Deslimed feed	99.1	14.2	8.4	2.1	0.45	68.5	72.1	29.3	0.55	0.27	0.11
C+F 1	Feldspar conc	72.4	18.3	11.1	2.6	0.43	89.0	66.1	9.4	0.57	0.26	0.11
	Flot tail	26.7	3.9	1.6	1.1	0.12	16.5	92.0	81.4	0.52	0.32	0.11
C+F 2	Feldspar conc	73.8	17.8	10.8	2.5	0.64	87.4	66.9	11.0	0.54	0.20	0.12
	Flot tail	25.3	3.4	1.3	0.7	0.15	14.2	92.8	84.2	0.55	0.29	0.10
C+F 3	Feldspar conc	72.9	18.1	10.9	2.5	0.60	88.2	66.5	10.3	0.55	0.24	0.10
	Flot tail	26.2	3.7	1.5	1.0	0.20	16.0	92.3	82.3	0.61	0.29	0.12

Distribution

Test	Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
C+F 1,2,3	Slimes	0.7	0.3	0.9	3.0	0.6	0.7	0.8	8.5	13.7	5.7
C+F -1	Feldspar	92.1	94.7	88.6	86.6	93.0	65.6	23.8	68.5	59.4	68.9
C+F -2	Concentrates	93.2	95.7	89.8	89.8	94.2	67.3	27.9	67.8	63.7	73.4
C+F -3		92.2	95.0	89.7	86.6	93.3	66.3	25.6	65.4	60.2	65.9

APPENDIX II (continued)

Part 3 - Results (Size Basis)

Test	Products	Wt %	Analysis, %									
			Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
C-1,2,3	Slimes	0.8	14.2	4.2	2.6	1.94	56.4	56.0	22.6	6.93	6.15	0.93
C-1	Feldspar conc	79.9	18.7	11.5	2.5	0.48	91.5	65.6	7.3	0.38	0.15	0.06
	Flot tailing	19.3	6.4	2.6	1.1	0.19	25.6	87.5	72.2	0.75	0.43	0.14
C-2	Feldspar conc	81.6	18.2	11.3	2.4	0.70	90.6	66.2	8.1	0.40	0.21	0.07
	Flot tailing	17.9	5.9	2.5	1.1	0.27	25.4	88.0	72.5	0.81	0.29	0.12
C-3	Feldspar conc	80.5	18.6	11.4	2.4	0.66	91.0	65.8	7.8	0.41	0.18	0.06
	Flot tailing	18.7	6.0	2.6	1.1	0.35	26.4	87.6	71.2	0.98	0.35	0.13
C-1,2,3	Feed (c)	100.0	16.1	9.7	2.2	0.56	78.5	69.8	19.8	0.52	0.25	0.08
F-1,2,3	Slimes	1.0	11.1	3.1	1.9	1.53	42.0	62.4	38.0	5.80	4.50	0.71
F-1	Feldspar conc	63.6	17.6	10.4	2.6	0.35	85.3	66.9	12.6	0.84	0.43	0.19
	Flot tailing	35.4	2.3	0.9	0.6	0.07	10.7	94.8	87.3	0.37	0.25	0.09
F-2	Feldspar conc	65.0	17.1	10.1	2.4	0.56	82.8	67.9	15.2	0.75	0.39	0.20
	Flot tailing	34.0	1.8	0.6	0.4	0.07	7.3	95.8	91.4	0.39	0.29	0.08
F-3	Feldspar conc	64.0	17.4	10.2	2.5	0.50	84.0	67.4	14.1	0.75	0.34	0.17
	Flot tailing	35.0	2.2	0.8	0.5	0.11	9.4	95.2	89.3	0.37	0.25	0.11
F-1,2,3	Feed (c)	100.0	12.0	6.9	1.8	0.35	57.6	77.0	40.4	0.70	0.38	0.16

Distribution %

Test	Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
C-1,2,3	Slimes	0.7	0.4	1.0	2.8	0.6	0.7	0.9	12.3	18.8	9.9
C-1	Feldspar	91.7	94.5	89.5	88.7	93.1	75.1	29.2	60.7	48.0	58.2
C-2	Concentrates	92.7	95.0	90.0	89.2	93.6	76.9	33.4	62.0	62.2	66.1
C-3		92.4	94.6	89.5	86.6	93.2	75.9	31.8	57.6	55.9	60.6
F-1,2,3	Slimes	0.9	0.5	1.1	4.4	0.7	0.8	0.9	8.4	11.7	4.5
F-1	Feldspar	92.4	94.9	87.7	86.0	92.8	55.5	20.4	73.6	66.7	75.5
F-2	Concentrates	93.9	96.5	91.0	89.7	94.9	57.1	23.9	72.0	63.6	79.0
F-3		92.7	95.4	89.1	85.3	93.6	56.0	22.2	72.1	63.0	70.5

APPENDIX III - FLOWSHEET A
(Data and Results)

Part 1 - Reagents and Conditions

Operation	Time min	Density % solid	Reagents Kg/t			pH
			NaOH	H_2SO_4	PDD	
Acid-leach*	6 h	50	-	40e	-	0.1
scrubbing (Desliming 2X)	15	75	5	-	-	13.1
Conditioning:	5	60	-	2.0	0.65	2.1-2.3
Flotation	4½	25	-	0.9	-	2.3-2.6

*Acid leach: 35% H_2SO_4, 70°C, and 1:1 solid liquid.
Dry HI-Stearns separations: 0.5 Tesla, minimum gap.
Wet, HGMS: 1.3 Tesla, 24 mm/s.

Part 2 - Weight and Analysis of Products

Products	Wt %	Feldspar components				Total Feldspar	Silica		Oxides		
		Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
Ceramic feldspar	35.5	18.4	11.3	2.7	0.43	91.8	67.1	7.6	0.079	0.04	0.026
Glass feldspar	35.5	18.3	11.2	2.7	0.41	91.1	67.3	8.2	0.11	0.04	0.045
Flot tailing	25.3	4.1	1.7	0.7	0.15	16.7	92.6	82.6	0.14	0.09	0.09
Fe concs	3.3	17.8	9.5	2.4	0.66	79.4	64.6	16.7	1.20	1.35	1.00
Slimes	0.4	11.5	4.5	2.1	2.10	54.8	68.0	35.0	2.27	1.58	1.43
Feed (calcd)	100.0	14.6	8.7	2.2	0.37	71.9	73.5	27.2	0.15	0.10	0.09

Part 3 - Distribution %

Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O	MgO	TiO_2
Feldspar concs	88.6	91.3	87.8	81.4	90.2	64.9	20.6	44.4	27.8	29.1
Flot tailing	7.1	4.9	8.1	10.3	5.9	31.8	76.9	23.4	22.3	26.3
Fe concs	4.0	3.6	3.6	6.0	3.6	2.9	2.0	26.2	43.7	38.0
Slimes	0.3	0.2	0.4	2.3	0.3	0.4	0.5	6.0	6.2	6.6

APPENDIX IV - FLOWSHEET B
(Data and Results)

Part 1 - Reagents and Conditions

Operation	Time min	Density % solid	Reagents Kg/t			pH
			NaOH	H_2SO_4	PDD	
Scrubbing (Desliming 2X)	15	75	5	-	-	13.6
Conditioning:	5	60	-	2.8	1.2	2.0-2.2
Flotation	4½	25	-	1.0	1.2	2.3-2.5

*Acid leach: 35% H_2SO_4, 70°C, 6 h and 1:1 solid liquid.
Dry HI-Stearns separations: 0.5 Tesla, minimum gap.
Wet, HGMS: 1.3 Tesla, 24 mm/s.

Part 2 - Weight and Analysis of Products

Products		Wt %	Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
Ceramic feldspar		22.2	18.2	11.4	2.6	0.33	91.0	66.8	8.4	0.08	0.04	0.02
Glass feldspar	Flint	22.7	18.0	11.3	2.5	0.35	89.7	67.1	9.7	0.12	0.04	0.03
	Colored	22 7	17.9	11.1	2.5	0.40	88.5	67.5	10.9	0.27	0.10	0.05
Flot tailing		24.9	4.5	1.8	1.0	0.22	19.6	91.4	79.0	0.47	0.20	0.10
Fe concs		6.0	16.0	8.3	2.3	2.00	56.9	62.8	24.8	3.60	1.80	2.03
Slimes		1.0	12.3	3.8	1.7	2.40	37.5	58.4	41.3	6.90	5.20	1.25
Feed (calcd)		100.0	14.5	8.6	2.1	0.44	70.8	72.7	27.1	0.51	0.25	0.18

Part 3 - Distribution %

Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O	MgO	TiO_2
Feldspar concs	84.8	88.6	81.5	55.5	86.5	62.9	24.3	20.9	16.3	12.4
Flot tailing	7.7	5.2	11.3	11.9	7.1	31.3	72.1	42.5	19.9	13.7
Fe concs	6.7	5.8	6.4	27.2	5.7	5.0	2.5	23.0	43.1	67.0
Slimes	0.8	0.4	0.8	5.4	0.7	0.8	1.1	13.6	20.7	6.9

APPENDIX IV - FLOWSHEET C
(Data and Results)

Part 1 - Reagents and Conditions

Operation		Time min	Density % solid	Reagents Kg/t			pH
				NaOH	H_2SO_4	PDD	
Scrubbing (Desliming 2X)		15	75	5	-	-	13.4
Conditioning	Coarse	5	60	-	0.9	0.50	2.1-2.3
	Fine	5	55	-	1.1	0.75	2.0-2.2
Flotation	Coarse	4	25	-	0.4	-	2.4-2.6
	Fine Rougher	5	22	-	0.5	-	2.2-2.5
	Fine cleaner	4	16	-	0.3	0.2	2.3-2.5

1st Acid leach: 35% H_2SO_4, 85°C, 5 h and 1:1 solid liquid.
Dry HI-Stearns separations: 0.5 Tesla, minimum gap.
Wet, HGMS: 1.3 Tesla, 24 mm/s.
2nd Acid leach: 35% H_2SO_4, 70°C, 1½ h and 1:1 solid liquid.

Part 2 - Weight and Analysis of Products

Products		Wt %	Feldspar components				Total Feldspar	Silica		Oxides		
			Al_2O_3	K_2O	Na_2O	CaO		SiO_2	Quartz	Fe_2O_3	MgO	TiO_2
Porcelain feldspar		17.2	18.2	11.3	2.68	0.31	91.0	66.9	8.4	0.049	0.04	0.01
Ceramic feldspar		17.2	18.6	11.3	2.65	0.34	90.8	66.5	8.6	0.076	0.04	0.02
Glass feldspar	Flint	17.2	18.9	11.8	2.70	0.28	93.4	65.9	6.0	0.11	0.04	0.05
	Colored	17.2	18.0	10.8	2.72	0.36	88.6	67.5	10.8	0.27	0.04	0.10
Flot tailing		26.0	4.3	1.7	0.76	0.12	17.1	91.4	81.2	0.55	0.56	0.11
Fe concs		4.4	16.7	7.6	2.88	2.07	78.6	63.5	11.5	3.78	2.16	1.29
Slimes		0.8	12.8	3.5	1.70	0.35	36.8	63.4	44.9	6.15	3.36	0.78
Feed (calcd)		100.0	14.6	8.6	2.2	0.34	70.6	72.0	26.8	0.44	0.29	0.12

Part 3 - Distribution %

Products	Al_2O_3	K_2O	Na_2O	CaO	Feldspar	SiO_2	Quartz	Fe_2O	MgO	TiO_2
Feldspar concs	86.9	90.8	84.8	64.0	88.6	63.7	21.6	19.4	9.4	25.2
Flot tailing	7.4	4.9	8.7	8.7	6.1	31.7	75.3	32.2	49.3	23.3
Fe concs	5.0	3.9	5.8	26.5	4.9	3.9	1.8	37.3	32.2	46.4
Slimes	0.7	0.3	0.6	0.8	0.4	0.7	1.3	11.1	9.1	5.1